XLI.—*Investigations upon the Structure and Natural History of the* Vorticellæ. By Dr. Richard Greef.

[Continued from p. 211.]

Body-cavity and Digestive Organs of the Vorticellæ.

We are indebted to Ehrenberg for the first correct notion of the nutritive apparatus of the Vorticellæ. Whilst, before his time, as has already been remarked, it was supposed that the body of these animals constituted a hollow bell open anteriorly, he showed that the anterior opening of the bell was closed by a ciliated disk, and that it was only behind this disk that a lateral orifice led into the interior of the body. He likewise correctly determined the position of the anus as an orifice separate from the mouth but lying in the same pit, which, as we have already remarked, must be regarded as an essential systematic character of the Vorticellan family. The mouth and anus were said to be united by a curved intestine hanging down to the bottom of the body; and to this, in accordance with his conception of the polygastric nutritive system of the Infusoria, the stomachal vesicles were supposed to be appended by small lateral cæca.

After the refutation of the polygastric nutritive system, especially by the striking observation of the constant circulation of the whole contents of the body in *Paramecium* (Focke), the knowledge of the digestive apparatus of the Vorticellæ made an important advance by means of the researches of C. F. J. Lachmann (of whose labours science was unfortunately so early deprived), whose beautiful and careful investigations form to a certain extent a new starting-point in the examination of the entire structure and natural history of these animalcules.

Lachmann showed that the cilia upon the ciliated disk are not placed in circles, as Stein stated, but run in a spiral line to the mouth, which, indeed, Ehrenberg had already distinctly seen, as appears from many figures in his great work on the Infusoria (*e. g.* Taf. xxv. fig. ii., Taf. xxviii. fig. iii. 3, 2 &c.). But to Lachmann's observations we are indebted for the exact determination of the course of the series of cilia, which commences on the right from the external aperture of the nutritive tube, previously called the buccal orifice, runs round the ciliated disk once or several times, and then descends in a curve intc the above-mentioned orifice and traverses the first part of the nutritive tube. This commencing portion he called the *vestibulum*, after the example of Johannes Müller. The vestibulum consequently forms a part of the ciliary spiral, and cannot well be regarded as the œsophagus or as a part of the food-tube, seeing that the anus also opens into it. The mouth therefore only commences at the end of the vestibulum, near the anus, which is situated in the same cavity. From the mouth, a short tube (the œsophagus) leads to the somewhat spindle-shaped terminal part of the nutritive tube, which is characterized as the *pharynx*. The nutritive particles attracted and carried into the above-described canal by the ciliary current collect in the first place in the pharynx into a morsel, which, when it has attained a certain size, is forced into the interior of the body, and here driven about with the soft gelatinous contents until it is either entirely digested or removed again to the exterior through the anus.

Lachmann made a particularly careful investigation of the question whether the pharynx is really the terminal part of the nutritive tube, or whether there issues from it a wider canal which receives the morsels from the pharynx, carries them forward for a certain distance in a curved direction (as appearances would seem to indicate), and only then passes them into the interior of the body; but he finally decides in favour of the entire absence of any further canaliform structure.

Lachmann, then, regards the whole inner space enclosed by the cuticula and the cortical layer as a *great digestive cavity* or stomach, and the mass of contents rotating in it as *chyme*. This is of great importance for the view which we have hereafter to expound.

With regard to the behaviour of the ciliary spiral above described and its relation to the vestibulum, as also with regard to the further course and mode of termination of the nutritive canal, Stein has completely accepted Lachmann's views. On the other hand, however, he, and with him many others, has expressed himself most decidedly in opposition to the conception of the interior space of the body as a digestive cavity and of its contents as chyme, inasmuch as he denies the existence of both the body-cavity and of the chyme filling it. He endeavours rather to reestablish the opinion that the whole contents are to be regarded as contractile sarcode, supporting himself chiefly upon the supposition that the limits of the body-cavity are not determinable, as the outer (cortical) parenchyma passes quite gradually into the interior parenchyma, and is intimately united with it at all points.

If we first of all take up what is certainly the most important question, namely that of the existence of a digestive body-cavity, which has been answered so differently by the two investigators, I will declare at once that my investigations have led me quite unavoidably to Lachmann's opinion, and that I cannot admit the arguments brought against it by Stein.

In the preceding section we have endeavoured to prove that the external coverings of the body which enclose the interior space consist of three different parts, namely the *external cuticula*, the *muscles* lying beneath this, and the *cortical layer* following upon these. Although with respect to what in the Vorticellæ and the Infusoria in general is to be regarded as cuticula or as muscles, and with respect to the relations of these two parts, we have been compelled to express opinions in some points at variance with those of Stein, we are nevertheless in general in agreement with him in regard to the actual existence of the cuticula and muscular fibres as separate parts. We have here therefore to do chiefly with the existence and interpretation of the *cortical layer*, especially in its relations to the interior space and its contents.

If we examine a living Vorticellan carefully and for a long time (for which purpose, of course, the species of *Epistylis* are best adapted, as with them we are not disturbed in observation, as with the contractile-stalked Vorticellans, by constantly repeated and sudden contractions causing the continual disappearance of the object), one of the most remarkable of phenomena very soon strikes us—namely, that apparently the whole mass of the contents of the body *is engaged in constant rotatory movement*. This is the rotation-current first observed by Focke and then by others in *Paramecium* and other Infusoria, and also by Lachmann in the Vorticellæ, which must so far be regarded as a discovery of importance, that it furnishes us with the clearest evidence against the nutritive apparatus ascribed by Ehrenberg to the Infusoria. The actuality of this rotation-current itself cannot be doubted; it is one of the constant and normal vital manifestations of the Infusoria in question. It is by no means, as Ehrenberg endeavours to establish for the further support of his system, a pathological phenomenon produced by pressure, displacement of the contents, &c. It is observed under all circumstances in the living animal, even when not the smallest altering influence, such as pressure &c., exists; and it may be most easily and distinctly recognized when the contents of the body are coloured, or when for this purpose a colour-diet (carmine) has been administered to the animals.

Epistylis flavicans, which has already repeatedly been referred to, is one of those species of *Epistylis* which are generally more or less intensely coloured yellow or yellowish brown by nature, and also one of the larger species; and in it, for other reasons also, the phenomenon now under discussion may be very well followed in all its details, for which reason, in what follows, we shall chiefly take it as the foundation of our observations. If we carefully examine the movement of rotation in *E. flavicans*, we find that this movement does not occur, as at first sight appeared, in all parts of the interior of the body. *The entire conical hinder part of the body, from the attachment of the peduncle nearly to the point where the bellied curve of the bell commences, takes no part in the movement* (Pl. XVI. fig. 1). This part also is not coloured, but hyaline, and only occupied by a few dimly shining granules; hence it is strikingly differentiated from the coloured contents of the bellied part of the bell (Pl. XV. figs. 1 & 18). One sees most clearly how the circulating mass of contents *flows past the inner wall of this conical hinder part without any portions of the latter being carried away by the current.* Evidently there is here a fixed boundary between the constantly mobile fluid contents and a firmer wall-parenchyma, which in the first place fills the whole conical base of the Vorticellan body, but from this rises like a cup on the lateral walls and lines the inner surface of the cutaneous covering above described, presenting everywhere a sharp boundary to the fluid contents of the body.

Of this also we may convince ourselves by observation, by carefully tracing the movement of rotation from the base through the cavity of the bell. It is clear from this that there can no longer be any question of a gradual transition of the fluid body-contents into the firm parenchyma of the walls, of an amalgamation of the whole into a common sarcode or protoplasm filling the body as a parenchyma; for the *rotation becomes brisker and more regular the further out it is*, and passes everywhere *with a sharp boundary by the inner walls of the circumference of the body.* If the contents gradually acquired more consistence and tenacity outwards, and became amalgamated here with the firmer cortical layer, which also, although reluctantly, would be drawn into the rotation, the movement must gradually diminish exteriorly. But precisely the reverse takes place, as already remarked. Moreover, if the cortical layer really rotated with the rest, how should we explain the fact that the contractile vesicle, the nucleus, the first part of the nutritive tube (vestibulum and œsophagus), the muscles, &c. are nevertheless still maintained in their definite position? Must not they also be carried away and thus continually change their position? Or we must assume that these organs are not situated in the cortical layer, but within the cuticula. But they lie, as may be most easily ascertained, beneath the cuticula and in the cortical layer, and are probably not at all in contact with the former. In Rhizopoda, which Stein adduces as objects of comparison and in support of his view, and especially in *Amœbæ*, such a differentiation into a firm, limited cortical layer and an inner space has not yet been evolved, nay in many cases even an outer skin cannot be demonstrated; in these, however, the organs of the body have not yet found any definite position, but they are driven about in the interior with the mass of contents. Nevertheless I am far from supposing the whole Amœban body, especially in the large, independent, infusorium-like *Amœbæ*, to consist of a simple homogeneous protoplasm; but no doubt, as I hope to demonstrate more completely on another occasion, we have here to distinguish various substances and structures differing from each other in form and vital manifestation. Far less can we declare that an animal body comparatively so highly organized as that we have before us in the Vorticellæ, consists of mere protoplasm. Might we not, with almost equal justice, refer a great part of the Cœlenterata, Vermes, &c. to the rank of protoplasmic creatures?

It is sufficient that the observations cited determine me to accept for the Vorticellan body a *cortical layer* situated under the cuticula and not rotating with the rest of the contents, embracing within, with a firm boundary, a space, the *body-cavity*, which therefore, as, according to what has been stated, the wedge-shaped hinder part of the Vorticellan body is filled with the firm cortical parenchyma, has a shape like that of a cup or finger-stall.

The contents of the body-cavity consist of a thinly fluid paste of incepted or more or less dissolved nutriment, *i. e.* of *chyme*, which, by the constant accession of fresh nourishment and water from without through the mouth, and by giving off exhausted material through the anus, is engaged in continual change. In the interior of the body-cavity this nutritive paste circulates constantly, as has been already fully described; and by this means the fine division and chymification (in other words, *the digestion* of the nutritive substances on the one hand, and on the other their diffusion through the whole body) are assisted. In the body-cavity of the Vorticellæ we consequently see a *gastrovascular space*, in the full sense of the words—a body-cavity in which digestion and circulation, *i. e.* nutrition, is effected in precisely the same way as in the Cœlenterata.

By no means can this paste be regarded as "consisting throughout of mere sarcode," as Stein mantains very decidedly in favour of the protoplasm-theory. Leaving out of consideration that such a universalization of protoplasm would lead us to remote and obscure paths, as was the case formerly by Dujardin's means, unprejudiced and careful observation is in this point also strongly opposed to any such conception. And according to this, the chyme when already elaborated into a homogeneous granular substance (or, to anticipate no opinions, the fundamental substance of the circulating paste) is not at all sarcode or protoplasm in the sense applied to the term by authors. For the movement of rotation, as careful examination shows, is not that of a tenacious, contractile substance; it does not manifest itself after the fashion of the amœboid, slowly creeping protoplasmic streams with which we are elsewhere aquainted, but it progresses everywhere easily and briskly, sometimes even with a *slightly tremulous* current, through the inner space. But how is this to be brought into agreement with the phenomena of motion which we are always accustomed to witness in the tenacious contractile protoplasm, and which must be regarded as characteristic of the latter. Is not the vibrating movement rather a proof that it is performed by a readily flowing, non-contractile substance, *i. e.* precisely not by protoplasm? Moreover, we must here again call attention to the phenomenon already insisted on in the examination of the cortical layer surrounding the body-cavity, according to which the current is briskest at the outer walls.

Stein requires also, as evidence of a body-cavity, that this, when its contents are evacuated, must also appear as an empty cavity. If we could effect a transverse section through the body of a Vorticellan (which, however, does not seem possible, considering the minuteness and delicacy of the object), we should, I have no doubt, be able to bring the body-cavity under direct observation; but even the examination of the uninjured living animal satisfies this requirement. Thus, if we isolate for a time in clear water, upon a glass slide or in a watch-glass, a newly captured Vorticellan with its bell distended with food, we may see how the food-balls are ejected one after the other. The body gradually becomes paler and more elongated; the walls acquire folds; and after the lapse of a certain time the well-fed convex Vorticellan becomes a slim collapsed animalcule, the integuments of which sink here and there into the evacuated stomachal cavity in deep folds and sinuosities.

But, instead of food, water is now taken up through the nutritive tube; and according as the access of this is abundant or scanty, the body-cavity becomes filled out or not so completely collapsed as above indicated. At the same time, however, the remarkable phenomenon which is very characteristic in the question now before us makes its appearance—namely, that the movement of the contents is much brisker than before, and may generally be recognized in a distinct vibrating current of the form-constituents still mixed with the water.

These form-constituents, which remain after the removal of the larger food-balls, are, moreover, in some species, of very constant form and size: for example, in *Epistylis flavicans* they consist of shining, light-yellow spherules, of which usually three or four, but often several, are massed together into comparatively large balls (Pl. XV. fig. 5), so that one is induced to regard the whole of the fluid, now freed from the coarser, still undissolved or insoluble nutritive materials, as the blood or chyle mixed with water.

The preceding observations and indications may for the present suffice for the establishment of my assumption of a digestive body-cavity in the Vorticellæ; and we now come to the second of the questions raised above, namely the nature of the alimentary tube leading into this digestive cavity. As has been already remarked, the correct position of the external orifice of the nutritive tube described by him as the mouth, as also the position of the anus, was first recognized by Ehrenberg. According to him the rounded buccal aperture lies directly behind the ciliated disk, and the anus in a pit in the initial portion of the nutritive canal which enters the body. Stein showed further that this buccal opening is situated between the ciliated disk and the peristome, and that from this point the nutritive tube, distinguished by him into pharynx and œsophagus, hangs down into the body. The food-balls were supposed to be pushed through the œsophagus into the parenchyma of the body, and in most cases the exhausted food to be carried back again in the same way. The most accurate description of the nutritive apparatus of the Vorticellæ was given by Lachmann*. He found that the cilia upon the anterior disk of the body took a spiral course, and, indeed, that in *Carchesium polypinum*, for example, this ciliary spiral commenced to the right of the external nutritive aperture called the mouth by Ehrenberg and Stein, and then turned away to the left over the latter and ran round the margin of the circular disk, to sink again at last into the buccal aperture and into the first portion of the alimentary canal (see Pl. XIV. fig. 9). At the bottom of this first portion (as Ehrenberg had already discovered) the anus was situated, for which reason the mouth in reality could only commence here. The initial portion, situated before this point, and including Ehrenberg's buccal aperture, was therefore described, after the example of Johannes Müller, as the porch of the digestive apparatus, the *vestibulum*. The vestibulum was continued into a thinner, short tube, the *œsophagus*, and terminated in a somewhat wider, spindle-shaped part, which was called the *pharynx*, through which the particles of food fall directly in balls into the soft parenchyma of the body. Stein* afterwards confirmed Lachmann's observations, and also on the whole adopted the designations chosen by him for the different parts of the digestive apparatus, the only alteration being that he includes the two parts distinguished as œsophagus and pharynx under the latter name, as he cannot distinguish Lachmann's pharynx from the preceding tube, called the œsophagus, by any, even functional separation. Both authors agree that there is no further canaliform continuation of the alimentary tube from the posteriorly pointed end of the pharynx, but that the alimentary materials accumulate in the latter, and afterwards sink into the parenchyma of the body which divides in an arched form.

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* Müller's Archiv, 1856, p. 340.

I must, in the first place, express my entire concordance with the observations of Stein and Lachmann as regards the ciliary spiral and the vestibulum in *Carchesium polypinum* and many others, especially of the smaller species of Vorticellæ (see Pl. XIV. fig. 9, in which the course of the ciliary spiral and its relation to the vestibulum &c. in *Carchesium polypinum* is shown). But in the larger species of *Epistylis* there is so far a deviation from this, that here the spiral is not confined to a single turn, but describes several turns upon the ciliated disk before sinking into the vestibulum; to this, indeed, Lachmann has already called attention. A multiple circle of cilia of this kind occurs, for example, in our *Epistylis flavicans.* In this Vorticellan, moreover, the digestive apparatus appears with so distinct and in part peculiar an arrangement, that we will once more adhere to it in the investigation of this question also. In *Epistylis flavicans* the anterior ciliated disk bears four circles of cilia (Stein and Lachmann state three), which apparently lie concentrically around one another. Easy as it is in many species of Vorticellans (*Carchesium polypinum*, *Epistylis plicatilis* and *parasitica*, *Zoothamnium alternans*, &c.) to detect the spiral course and the final bending into the vestibulum of the series of cilia, it is just as difficult in *Epistylis flavicans*, probably chiefly because in this the so-called "peduncle" of the ciliary organ is deficient. The peristome seems rather to come directly against the ciliated disk as a thin border turned back when the bell is fully opened, without being separated from the disk, as in most Vorticellæ, by that deep furrow from within which the "cap-like" ciliary organ rises. The external aperture of the alimentary canal therefore, so far as I have as yet been able to see, is situated not merely behind the ciliated disk, but also, differently from the other Vorticellæ, behind the peristome (Pl. XVI. fig. 1, and Pl. XV. fig. 5, *ff*). Fromt his aperture (Pl. XVI. figs. 1 & 2, *m ff*) a tolerably wide canal runs inwards directly behind the ciliated disk and parallel to its plane; it then makes a knee-like bend (Pl. XVI. fig. 1, *h*) and, gradually becoming narrower, runs again to the buccal (ventral) side and then backwards, describing in its course two or three more slight curves. As far as the knee-like bend, according to Lachmann, the initial part of the alimentary canal, the so-called vestibulum, extends. At the bottom of the cavity of this knee, behind a long bristle which traverses the whole initial portion of the alimentary canal and projects from the external aperture (Pl. XVI. fig. 2, *ff*) the *anus* is situated (fig. 2, *h*); and here, therefore, according to Lachmann, the mouth should begin.

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* Der Organismus der Infusionsthiere, ii. pp. 84 *et seqq.*

This determination of the buccal and anal apertures and of the initial portion of the alimentary tube as the vestibulum, has certainly some justice on its side; but in my opinion it would render the whole conception of the alimentary canal simpler if we were to retain the designation mouth for the external aperture. That the anus opens into this initial portion of the alimentary canal, and that consequently the external aperture serves at once for the introduction of food and for the evacuation of exhausted materials, need not prevent our designating it as the buccal aperture. We find precisely similar conditions in all Cœlenterata and in many Echinoderms and worms, in which a special anus opening outwardly cannot be detected. Must we not in this case, for example, characterize the alimentary sac of the Anthozoa also as a vestibulum, and place the aperture of the mouth at its open posterior end, as here also the true orifice of ejection begins (that is to say, it opens into this initial part of the alimentary canal)? Moreover, if we admit in designation and conception that this vestibulum is to be regarded as the *initial part of the alimentary canal*, we need not hesitate to accept the beginning of this initial part, *i. e.* its external aperture, as the *buccal aperture*. At any rate by this means the whole conception of the alimentary canal, and especially its description and terminology, would be materially facilitated and simplified. Lachmann's *vestibulum* would then, as formerly, be designated the *pharynx*; and in this we are justified by a peculiar arrangement which exists in the kneed cavity of the end of this pharynx. Thus we see distinctly that the particles of food, driven into the mouth by the ciliary current, first of all reach this point, and are then carried either back again and out through the mouth or into the following section of the alimentary canal. To effect this there are, in *Epistylis flavi-*

cans, *two valve-like partitions* (Pl. XVI. fig. 2, *k* & *k'*), which occur in the posterior cavity of the œsophagus, the true pharynx, and which, aided by the corresponding ciliation, determine the direction of the two opposite currents.

From the œsophagus, or, if it be preferred, the vestibulum, the alimentary canal is continued as already described, making a curve and running, backwards and towards the ventral side, in a tube furnished with proper walls and gradually becoming narrower, which then finally, according to observations up to this time, passes into a portion which is a little widened anteriorly and pointed posteriorly, and here terminates. In this terminal portion the food driven by the ciliary current into the digestive apparatus, is collected into a ball, and then pushed directly into the parenchyma of the body. This part of the alimentary apparatus from the issue of the vestibulum (*i. e.* from the inner buccal opening) to the spindle-shaped terminal portion, was called by Lachmann the œsophagus, and only the terminal portion itself the pharynx; whilst Stein names the whole from the vestibulum, and therefore both the œsophagus and pharynx of Lachmann, the pharynx. According to the above statements with regard to the desirability of the denomination "vestibulum" for the initial portion, if we should give the name of pharynx to this latter, the above-described terminal portion must of course be regarded as the œsophagus.

But let this be as it may (as in it we have to do rather with a more or less desirable conception and terminology than with actual observation), the results of investigations up to this time all agree to show that behind this spindle-shaped dilatation of the pharynx or œsophagus there is no trace of special food-passages, but that the digestive canal here fully comes to an end.

Nevertheless, notwithstanding the careful investigations of Lachmann and Stein relating to this point, I must affirm, from my own observations, that, at least in *Epistylis flavicans*, this supposed terminal portion is really continued for a considerable distance further into the body-cavity as a closed canal with proper walls.

Of this we may convince ourselves in two ways:—first, by the direct observation of the canal in question within the body-cavity, nay, even by isolating it; and secondly, by subjecting the animal to a colour-diet, so as to trace the course taken by the coloured (*i. e.* the food) particles. Let us first of all take up the former as the direct and most certain course, and employ the second, which has been already so often tried and which so easily leads to delusions, only for the completion of our researches.

When a colony of *Epistylis flavicans* has been kept for a time isolated in clear water, the food-balls circulating in the body-cavity are all, as already stated, gradually expelled through the anus. By this means the animals, which are otherwise of a yellow or yellowish-brown colour, become paler and more transparent, and render it possible to get a better insight into the interior space of the body. When a Vorticellan thus prepared is examined under careful compression and in a suitable position, we see clearly in the first place the course of the whole of the above-described alimentary apparatus from the buccal aperture (Pl. XVI. figs. 1 & 2, *m*), through the vestibulum (pharynx) and the œsophagus (figs. 1 & 2, *o*), to the spindle-shaped terminal portion (*v*), and at the same time that the whole of this passage is clothed with briskly striking although comparatively few cilia. The end of this canal, however, the spindle-shaped dilatation which has been repeatedly mentioned, is, in *Epistylis flavicans*, not as represented by Lachmann and Stein and as appears to be the case in most other Vorticellæ, a simple continuation of the canal preceding it (the œsophagus), but it presents itself as a *bellied funnel distinctly marked off* from the latter (Pl. XVI. figs. 1 & 2, *v*), which embraces the end of the canal opening into it, and the posteriorly directed point of which, as may be most distinctly seen under favourable circumstances, passes into a *fine canal* (figs. 1 & 2, *d*), which describes a broad curve in the bottom of the body-cavity and suddenly breaks off, *i. e.* opens freely into the body-cavity, on the side opposite to the funnel and about at the level of its commencement. The whole canal, from the point of the funnel to its termination, when not dilated by nutritive material or water, is more or less collapsed, and consequently, in this state, appears as a clear curved line or fine streak. Sometimes by carefully and gradually compressing the body until it is crushed, at the same time keeping the clear curved line uninterruptedly in view, we may succeed in recognizing and tracing it for a certain distance in the effluent contents, which are quite out of their natural position. This phenomenon, however, which is therefore to a certain extent equivalent to an isolation of the part under consideration, is, I think, decisive, as it can only be explained by the presence of an actual canal.

After this direct observation, which may certainly often be attended with great difficulties and by frequent failure, with much loss of time caused by constant repetitions, we may confirm and complete the picture thus obtained in the most beautiful manner by administering a carmine diet to our animalcules, but at the same time meet with new difficulties in the way of this conception.

We see, in the first place, how the particles of carmine are carried by the circles of cilia of the ciliated disk towards the external aperture of the alimentary canal (buccal aperture) situated on the margin of the peristome (Pl. XVI. fig. 1, *m*), and here, for the most part, again thrown back in an eddy towards the opposite side, whilst only a comparatively small quantity passes into the vestibulum (pharynx). But even of these last most of the particles are again expelled from the deeply excavated bottom of the vestibulum, in which process the above-described valve-like partitions in the cavity of the vestibulum (pharynx) conduct the two opposite currents. (See Pl. XVI. fig. 2, in which the arrows indicate the different directions of the currents caused by the partitions (*k* & *k'*) and the ciliation.)

Those coloured particles which have freely passed the vestibulum are now generally rapidly forwarded through the canal which follows (figs. 1, 2, *o*), by means of the cilia which work briskly within it, fall into the funnel (*v*) and here stop, until this receptacle is gradually completely filled with coloured material. At the same time, however, water is of course carried in through the alimentary tube, so that the ball of coloured material appears to be surrounded by a hyaline vesicle. When the cavity of the funnel is more or less tightly filled, its point, which is directed backwards, opens sooner or later (sometimes when only a small quantity of coloured material has accumulated, and then perhaps by the pressure of the water); and then the whole of its contents, in the form of an elongated spindle-shaped morsel, glides at first backwards to the bottom of the body-cavity (Pl. XVI. fig. 1, *b*, *b*), to turn forward again in a curve about to the level of its point of issue. On its arrival here we see a small button suddenly make its appearance (fig. 1, *b'*) on the anterior pointed end of the little coloured body; and immediately afterwards the whole morsel coalesces into a spherical ball. During its whole course, the lumen of the canal, opening in front and closing up behind it, may be very distinctly traced. It is well worthy of notice, in connexion with the whole process, that the velocity with which the spindle-shaped corpuscles of coloured material glide over the course just described is quite different from that of the movement of the rotating nutritive jelly (*i.e.* it is much greater, and uniform throughout), and that this velocity ceases suddenly and indeed at the very moment when the morsel coalesces into a spherical ball in the manner described above. The coloured ball now lies evidently imbedded in the nutritive jelly of the body-cavity, at first still surrounded by a hyaline cyst (water), and is then slowly carried along with this nutritive jelly.

The change of form and movement of the coloured corpuscles is so remarkable and sudden that it cannot be explained except by the existence of a curved canal starting from the apex of the funnel. This is especially evident at the moment when the elongated, pointed, and rapidly gliding morsel suddenly stops, projects with a little knob from the narrow canal, and then apparently falls immediately from it and into the body-cavity. It is not to be imagined that the described phenomena could be produced by the balls of coloured material being pushed directly from the funnel without the intervention of any canal into the nutritive jelly of the body-cavity, especially as frequently one morsel after another traverses precisely the same curve in the same compressed spindle-shape, the whole course being often even beset with carmine particles arranged in a row, so that they shine forth from the interior like a red curved line. Thus the coloured particles often remain long within the canal marking its course, whilst all around the rotating movement of the nutritive jelly is maintained. It is clear that, if these coloured particles had simply fallen from the funnel into this nutritive jelly, they must have been carried along by the current of the latter, especially the small carmine granules, and that they could by no means have remained continuously arranged one after the other in a curved line.

When one has had the above-described pictures before one's eyes, both in the way of direct observation and of carmine feeding, one can hardly doubt that in reality a canal exists, running from the apex of the funnel in a curve in the bottom of the body-cavity and then opening freely into the latter.

But we must not overlook the fact that, besides these distinct and striking phenomena, others also come under observation, which, again, are of a kind to raise doubts as to the existence of a special canal, and which, indeed, have led Lachmann and Stein to deny the presence of such a canal. Amongst these there is, in the first place, the fact that the curves described by the balls of carmine, *i.e.* the nutritive material issuing from the funnel, are not always the same, but are sometimes wider and sometimes narrower. This, however, in my opinion, is to be explained in the following way:—The whole alimentary tube, from the external buccal aperture situated behind the ciliated disk, to the funnel, has a definite form and position not subject to change. It lies, as has already been remarked, within the comparatively firm *cortical layer* enclosing or forming the body-cavity, and is retained in its place by this. But the fine curved tube issuing from the funnel is *no longer fastened by the cortical layer, but hangs free in the body-cavity*, and may therefore undergo a change of position now and then by the movements of the nutritive jelly circulating around it. Moreover it is easy to understand that the loosely pendent tube may even be more or less curved, according to the size of the morsel &c. It is also to be borne in mind that under these circumstances mistakes may very easily occur, and that we may fancy that we perceive a change of curve, whilst it may be only that either by twistings of the animal itself or by displacement of the tube the direction of the curve has become different, especially by the fact that at one time the free end of the tube is turned to the side, and at another more or less towards the observer. This also explains why, when a Vorticellan is sufficiently compressed, the curves are usually most regular, as by the mere compression of the body the movements and changes of position of the tube are limited.

Another objection against the existence of a distinct canal is, that the morsel pushed in from the funnel does not always traverse the same course, but escapes at a greater or less distance from its original point of issue. But this appearance may also in many cases be produced by the above-mentioned changes of position of the movable tube. On the other hand, under certain circumstances, especially when the body-cavity is for the most part emptied of its solid constituents and filled with more or less fluid contents, and therefore with a diminished pressure, the delicate tube appears to possess a great extensibility, in consequence of which the morsels gliding through it may then become balled together and widened earlier than otherwise. This applies especially to water, which, when accumulated in the funnel and transferred into the curved tube, dilates the latter by forming a large drop, which only disappears gradually by mixture with the nutritive jelly.

The above-cited observations, as already remarked, apply especially to *Epistylis flavicans.* In the other Vorticellæ I have been unable to demonstrate the canal in question with the same certainty, although in many others also I have been able to ascertain by direct observation the fine linear continuation of the apex of the funnel into the body-cavity. It is possible, however, that in other Vorticellæ this tube is shorter than in *Epistylis flavicans*, or perhaps that it may occasionally be entirely wanting—for example, immediately after fission; upon these points further observation may decide. Moreover the *Epistylis* under notice also differs from the allied forms inasmuch as in it the bellied, pyriform funnel always seems to be distinctly marked off from the preceding œsophagus, and is consequently to be regarded as a special part. In consideration of this, we might perhaps see in this funnel the first attempt at the formation of a stomach with proper walls, and in the curved canal issuing from it a likewise very primitive intestine.

[To be continued.]